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Surficial Geology of The East Stroudsburg 7½ Minute Quadrangle Monroe County, Pennsylvania

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COMMONWEALTH OF PENNSYLVANIA
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TOPOGRAPHIC AND GEOLOGIC SURVEY
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by Milena F. Bucek

Cooperating Geologist

PENNSYLVANIA GEOLOGICAL SURVEY

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PREFACE

This report describes the surficial deposits in the East Stroudsburg quadrangle, interprets their origin, and discusses their use. Information included in this report will be of use to students and professional geologists interested in glacial geology. Engineers concerned with highway and building construction and source material for construction will find the information very useful.

Surficial deposits have been used abundantly in eastern Pennsylvania and there is considerable potential for commercial exploitation in the East Stroudsburg Quadrangle. Representative samples of the deposits were collected and are described in this report.

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SURFICIAL GEOLOGY OF THE EAST STROUDSBURG QUADRANGLE

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ABSTRACT

The East Stroudsburg Quadrangle lies within Monroe County and is part of the Pocono Plateau Section of the Appalachian Plateaus Province. The studied area is located a few miles inside the Wisconsin end moraine and is covered by a variety of glacial deposits.

The deposits of an active flow are streamlined ridges and longitudinal intervening depressions of drumlinoid moraine and ground moraine with gently undulating topography strongly controlled by the preglacial surface of the underlying bedrock. The lateral moraines, as well as the terminal moraine which occurs east of Beakleyville, were deposited during deglaciation when the glacial ice was mainly confined to the topographically lower parts of the area.

The direction of the ice movement is indicated by the alignment of the drumlinoid moraine, striae trends, and also in the lithology and distribution of the glacial drift.

In the central and northern part of the area the movement was almost due south while farther to the south the advancing ice was deflected slightly to the west by the prominent topography of the Godfrey Ridge and Kittatinny Mountains.

The deglaciation of the area was marked by two major still-stands of the retreating ice succeeded by a disintegration of the stagnating ice which resulted in the deposition of kames, kame terraces, deltaic terrace and eskers, and development of the valley trains.

The hummocky ice disintegration topography was formed during the last phases of the deglaciation when buried ice blocks finally melted. The lithology of the drift is closely related to the underlying Devonian shale, siltstones, and sandstones.

(Spodosols of the "Seventh Approximation") are the main soil types developed on the glacial drift. Transitional bogs of low-moor and forest types also occur. Alluvium and colluvium are the most extensive post-glacial deposits.

INTRODUCTION

The East Stroudsburg Quadrangle is in the southern part of Monroe County and lies within the Pocono Plateau Section of the Appalachian Plateaus Province (W. D. Thornbury, 1965).

The work was done for the Pennsylvania Geological Survey, Harrisburg, and involved a study of the glacial deposits of the region and their economic evaluation. A reconnaissance survey of the bedrock geology and its relation to the lithology of the glacial drift was also performed. The field work took place in the summer and autum of 1968.

The author wishes to express her appreciation to W. D. Sevon for his helpful assistance during the field work and in the preparation of this report as well as to J. D. Glaeser and S. I. Root of the Pennsylvania Geological Survey and J. B. Epstein of the U. S. Geological Survey.

PHYSICAL GEOGRAPHY

The East Stroudsburg Quadrangle is underlain by Devonian sedimentary rocks and is covered with a blanket of the Wisconsinan glacial drift in more than 60 percent of the area.

The Borough of East Stroudsburg, situated in the southern part of the area, is the cultural and economic center of the region while scattered settlements to the north represent a part of the Pocono recreational area.

The region has a humid, temperate climate. Almost 70 percent of the quadrangle is covered by deciduous forest with only a small part of the land used for agricultural purposes.

The terrain of the region is characterized by the southward sloping plateau with broadly undulating summits and relatively steep-sided southern slopes. Two major morphological trends characterize the topography of the uplands of the area. The bedrock topography is adjusted to structure and lithology with the trend of abundant southwest-northeast oriented bedrock hills and ridges in general agreement with the prevalent strike of the strata. This morphological element is crossed by an alignment of constructional drumlinoid ridges with their long axes in a north-south direction. The general direction of the strike of the Devonian strata is also reflected by the broad preglacial valley in Smithfield Township between Marshal Creek and Beakleyville filled by glacial drift and alluvial deposits.

The highest point of the area is 1160 feet above sea level in the north part of the quadrangle near Manzanedo Lake. The undulating uplands range in altitude from 700 to 1100 feet; the dissected plateau ranges in relief from 200 to 300 feet. The greatest relief is south of Analomink where the high peak underlain by Trimmers Rock Formation is at an altitude of 920 feet and the nearby valley bottom of Brodhead Creek is at 490 feet. The lowest point of the quadrangle is south of the North Water Gap, where Marshall Creek leaves the quadrangle at an altitude of 335 feet. The Trimmers Rock Formation is the most resistant lithic unit of the bedrock and its outcrops form a topographically significant belt of northeast-southwest oriented peaks.

Figure 1. Drainage, network of the East Stroudsburg Quadrangle.

Two major streams, Brodhead and Marshall Creeks, (Figure 1) and their tributaries, drain the East Stroudsburg Quadrangle into the Delaware River, which enters the quadrangle in the southeastern corner. These streams flow in south and southeast trending valleys which are rather narrow except for the southern part of Brodhead Creek. The topographic differences of the valleys are related to their glacial history.

The topographic development of the region strongly reflects the erosional and depositional effects of glaciation as described in this report. This effect is also shown by extent of drainage development and alignment of numerous streams in the area (Figure 1).

BEDROCK GEOLOGY

A reconnaissance study of the bedrock geology in the East Stroudsburg Quadrangle was undertaken with the assistance of W. D. Sevon and J. D. Glaeser, Pennsylvania Geological Survey, and J. B. Epstein, U. S. Geological Survey. The Middle and Upper Devonian Marcellus, Mahantango, Trimmers Rock, and Catskill Formation were mapped and the contacts between units are shown on Plate I. The underlying Lower and Middle Devonian sandstones, limestones, and shales which occur in the southeastern part of the quadrangle were not differentiated and were mapped as one unit. Some dips and strikes are included on the map to indicate structure of the bedrock.

PRE-MARCELLUS ROCKS

The rocks underlying the Marcellus Formation compose the hilly area of the southeastern part of the area (Plate I) and consist of an undifferentiated series of calcareous siltstones and shales (Schoharie and Esopus Formations), black cherty limestones (Buttermilk Falls Formation), and white sandstones (Oriskany Formation). Differentiation of these units was considered beyond the scope of this report and was not attempted although the area is only partly covered by glacial drift and outcrops are common.

MARCELLUS FORMATION

The Marcellus Formation is a dark gray to black shale which underlies the broad, flat valley between Marshall Creek and East Stroudsburg. No outcrops of the Marcellus shale were found: however, outcrops of the shale seen elsewhere in the region indicate that the Marcellus is an easily erodable unit. Water wells in the area indicate a thickness of about 40 feet of glacial drift overlying the Marcellus in the mapped area.

MAHANTANGO FORMATION

The Mahantango Formation is only partly covered by glacial drift and outcrops show dark gray siltstones sometimes interbedded with silty shale. Some zones of the formation are very fossiliferous and the "Centerfield" coral zone (Beerbower, 1957) outcrops along Pennsylvania Route 191 two miles due north of the southern quadrangle boundary. Another good exposure of this unit occurs along the east side of Pennsylvania Route 447 at the junction of that route with Pennsylvania Route 191. The silt-

stones and shales break up into irregularly shaped pieces during weathering and are moderately resistant to erosion. The outcrop belt of this unit is a zone of moderate relief marked on the south by the lowland underlain by the Marcellus shale and on the north by higher ridges upheld by the overlying more resistant Trimmers Rock Formation.

TRIMMERS ROCK FORMATION

The Trimmers Rock Formation consists of a succession of massive to thin bedded greenish gray sandstones and siltstones characterized by conspicuous and abundant sedimentary structures such as cross bedding, load casts and groove casts. The Trimmers Rock is one of the most resistant units of the mapped area and forms the prominent hills and ridges which trend northeast from the Beacon Hill area southwest of Analomink. This formation is well exposed along the east side of Pennsylvania Route 447 about a half mile south of Analomink.

CATSKILL FORMATION

Towamensing Member

The Towamensing Member of the Catskill Formation is a series of gray to greenish gray sandstones characterized by well developed bedding with a tendency to break into flagstones. Large scale cross bedding is common and often well developed. The unit is as resistant to erosion as the Trimmers Rock and is not distinguished topographically from that unit. The sandstone is best exposed in an old quarry on the west side of Brodhead Creek at Analomink.

Walcksville Member

The Walcksville Member of the Catskill Formation underlies about half of the East Stroudsburg Quadrangle. The unit comprises a series of red siltstones and shales and green to gray siltstones and sandstones. This unit is best exposed in cuts along the Delaware, Lackawanna and Western Railroad north of Analomink.

Besides the specific localities already mentioned, all described rocks are exposed along the valleys of Brodhead, Paradise, and Marshall Creeks.

STRUCTURE

The area of undifferentiated pre-Marcellus Rocks appears to be structurally complex and no attempt has been made to define the structure of this area although it appears to be a broad anticline.

In the remainder of the area the rocks have a dominant low to moderate north dip and a regional N55°E strike. Exposures of the Walcksville Formation along the Delaware, Lackawanna and Western Railroad north

of Analomink show that numerous small assymetrical anticlines occur with steeply dipping south limbs and gently dipping north limbs. These folds are part of a broad synclinorium which has its axis north of the mapped area.

The moderate to low north dip of the rocks in the northern two thirds of the area combined with the alternation of hard and soft beds in many units (e.g., Walcksville Member) and erosive force of glaciation has resulted in numerous small ridges with north facing dip slopes and south facing scarp slopes. Many of these ridges have a relief of 10 feet or less and are not apparent on the topographic map.

GLACIAL HISTORY

The East Stroudsburg Quadrangle lies eight and more miles northeast of the proximal slope of terminal Wisconsinan end moraine. The terminal moraine was first mapped and described by Lewis (1884). Its occurrence and stratigraphic position were discussed mainly in the studies of Ward (1934, 1938) and more recently by Epstein (1969).

Any detailed stratigraphic evaluation of the glacial drift of the East Stroudsburg Quadrangle seems premature in this initial stage of detailed study of the northeastern Pennsylvania glaciation. The same is true of any attempt at correlation with rather remote areas of south-central New York state where the nearest substages of the Wisconsinan glaciation were defined by Muller (1965). However, the degree of weathering of the drift suggests deposition during Woodfordian stage of Frye (G. G. Conally, pers. com.).

The last glacial ice sheet invaded the area from the north. The direction of the advancing ice was almost due south in the north and central part of the area while in the southern part the ice was deflected to the southwest by the prominent topography of Kittatinny Mountain. The direction of ice movement is indicated by the alignment of drumlinoid ridges, the trend of striae and also by the composition of the glacial drift. Even the highest peaks of the southward sloping dissected plateau show either erosional or depositional effects of glaciation.

The lithology of the glacial drifts shows that it was derived predominantly from the underlying bedrock by glacial erosion during the ice advance. Abrasion and quarrying of the bedrock, development of the step-like long profiles (Figure 2) are some of the erosional effects of the advancing ice. Drumlinoid ridges and some ground moraine were formed during this stage of ice advance, the streamlined shape of the drumlinoidal topography offering minimum resistance to the overriding ice.

At the beginning of deglaciation a gradual thinning of the glacial ice took place and the upland areas of drumlinoidal topography were first free of ice. The ice lobes were gradually confined to the lower parts of

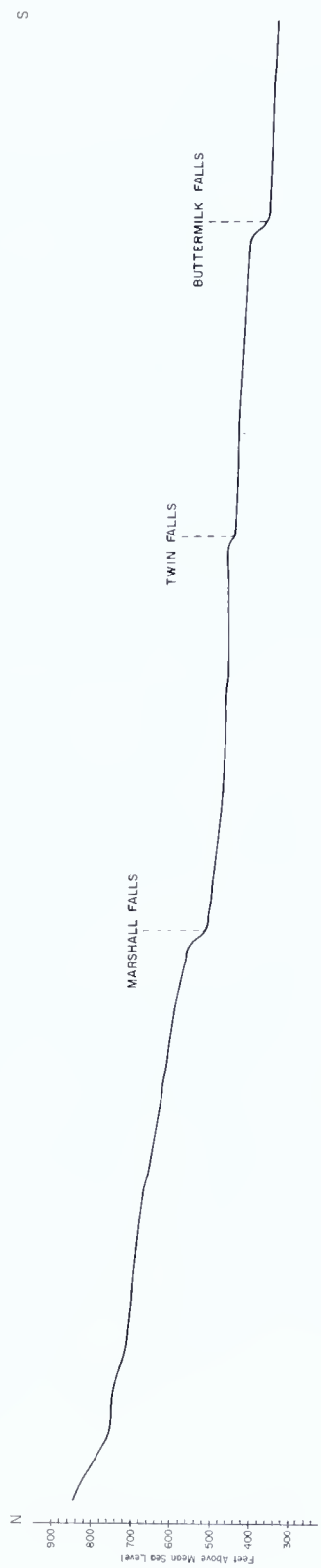

Figure 2. Longitudinal profile of Marshalls Creek.

the area, mainly the Brodhead and Marshall Creek valleys, the broad valley between Beakleyville and Marshall Creek, Middle Smithfield Township and the valley of Pine Mountain Run. The lateral moraines and the end moraine east of Beakleyville were deposited at this stage. Periglacial weathering of the glacial drift and the exposed bedrock started at this time. The downslope movement of the ice lobes was accompanied by partial melting of the ice and resulted in the deposition of very sandy and gravelly drift.

The transition from glaciation to deglaciation is characterized by intense climatic fluctuations and is reflected in periods of still-stands and sometimes local readvance. Two still-stands of the retreating ice margin and the subsequent disintegration of the stagnating ice took place in the area and were marked by the deposition of ice-contact drift in form of kames, kame terraces, eskers, pro-glacial outwash plains and valley trains. Hummocky moraine was also deposited in the final stages of stagnation with ice blocks buried in the topographically lower parts of the area.

The southern part of the quadrangle in the vicinity of East Stroudsburg and the lower part of Marshall Creek are covered by stratified drift of the older of the two still-stands. A subsequent still-stand of the ice margin is marked by ice-contact deposits in the northern part of Brodhead Creek and in Middle Smithfield Township and by the development of the valley trains. The valley train in Brodhead Creek is associated with the dissection of the stratified drift of the older still-stand.

An outwash plain was formed on the distal slope of the moraine east of Beakleyville and two gaps mark the position of the melt-water channels. During the melting of the ice lobe from the Beakleyville-Marshall Creek Valley a lake was formed between the proximal side of the Beakleyville end moraine and the ice margin to the northeast. This lake probably existed during the development of the Marshall Creek valley train and during the disintegration of the large body of ice confined to Middle Smithfield Township. The deposition of ice contact stratified drift and the development of many drainage channels carved in the till are associated with the stagnation of this ice. The deposition of the valley train in Marshall Creek Valley is associated with a deltaic terrace formed when the transported load was discharged into the Beakleyville-Marshall Creek lake.

The development of the soil profiles, colluvial deposits, alluvium, peat bogs and post-glacial erosion started as soon as the area became ice free.

GLACIAL EROSION

The movement of ice during the last stages of the glaciation was almost due south. During this time the most prominent of the preserved striae and grooves in the northern and central part of the area were

formed. In the southern part of the quadrangle the ice movement was deflected to the west by the prominent topography of Godfrey Ridge, Beacon Hill, and Kittatiny Mountain. Figure 3 shows trends of the glacial striae in the East Stroudsburg Quadrangle. Two prominent directions of the striae are S 18°W, S 42°W, and reflect ice movement with a minimum of influence by local bedrock topography. The predominant striae are often crossed by other sets of striations with different trends such as S 60°E, S 80°E, S 25°W, S 65°W. These diverging striae seem to reflect the influence of local topography since the striae measured in the valley tend to parallel the trend of the valley while those on hills parallel the trend of the hill. They were probably formed during de-

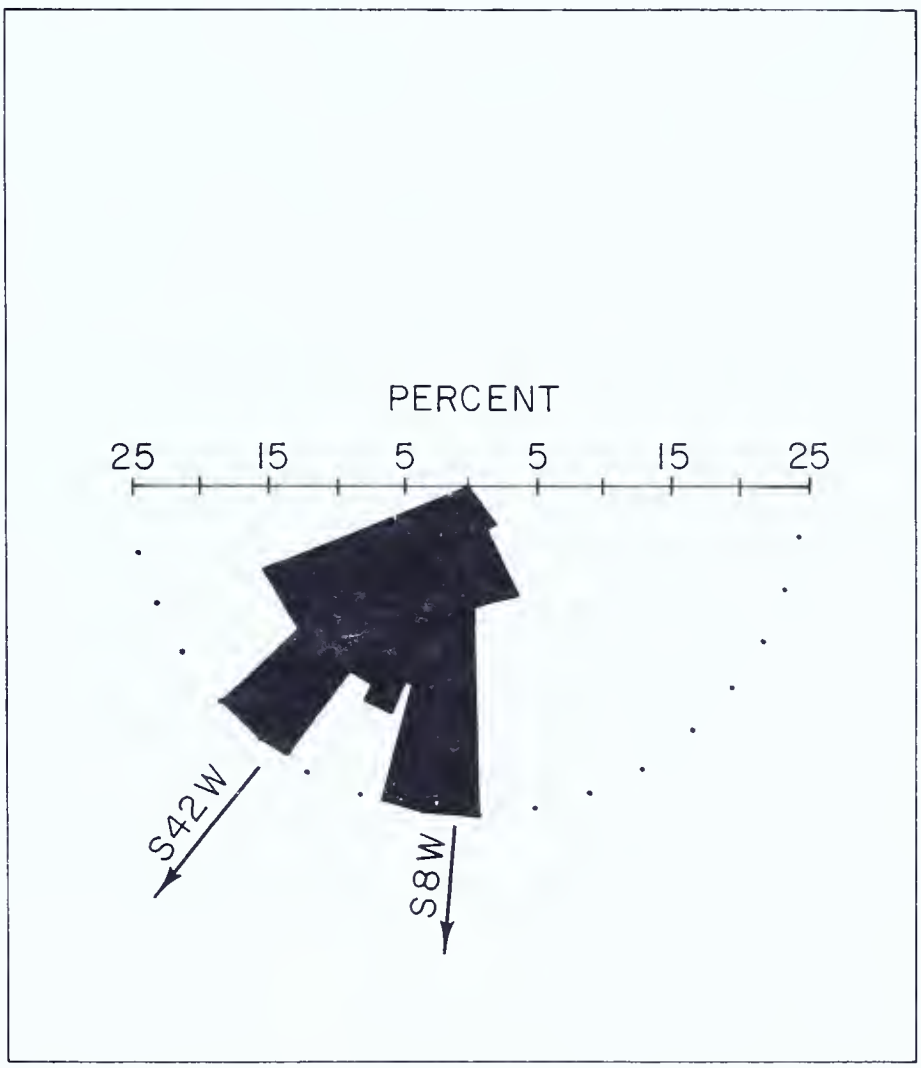

Figure 3. Rose diagram showing trends of the 85 glacial striae measured in East Stroudsburg Quadrangle. Arrows indicate two predominant trends of striae.

glaciation when the ice had so decreased in thickness that direction of movement was controlled by the local topography.

The gently sloping stoss slopes of many of the hills and ridges parallel the bedding planes of the underlying strata and the direction of the ice movement makes an angle of 120° with the strike of the strata.

Crescentic gouge marks were observed on a bedding plane of very fine-grained Catskill sandstone near Marshall Falls. The long axis of these marks is oriented in S 20°W direction.

The distribution of observed glacial striae in the area is irregular since much of the area is covered with glacial drift and colluvial deposits. The bedding surfaces of the Devonian very fine- and fine-grained sandstones have the best preserved and best developed striae.

Extensive glacial quarrying of the uplands of the region occurred during ice advance and resulted in an abundance of locally derived material in the glacial drift. Numerous hills and ridges project through the glacial drift cover. These hills and ridges were mostly formed by erosion preceeding glaciation, but the present round shape, the polished surfaces, the abrasion of their stoss slopes, the quarrying of their lee slopes, and the accumulation of angular material at the base of the lee slope are the result of glacial erosion. Some contribution of angular debris may be of periglacial origin also.

The glacial erosion affected not only the development of the uplands of the region, but also the characteristics of the valley. The tributary valleys with water falls and cascades above the main floor of Brodhead Creek, Marshall Creek, and the broad Marshall Creek—Beakleyville valley are the result of an erosional deepening of the main valley floors. A vertical drop of most of the tributary valleys is almost 300 feet in a distance of about one half mile.

A long profile of Marshall Creek shows a step-like development (Figure 2). This feature is attributed to differential glacial erosion of the underlying rocks. Several water falls and rapids occur in the valley of Marshall Creek, with the most prominent Marshall Falls and Buttermilk Falls. The only step in the profile of Brodhead Creek occurs south of Analomink where the creek crosses siltstones of the Trimmers Rock Formation. The absence of a well developed step-like profile in Brodhead Creek probably results from the glacial drift fill in the valley which would obscure any bedrock steps.

GLACIAL DEPOSITS

Three main groups of the glacial deposits were mapped and studied in the East Stroudsburg Quadrangle. The first group comprises unstratified drift or till with associated landforms such as ground moraine, drumlinoid till ridges, hummocky stagnation drift, and lateral and end

moraines. The second group is ice-contact stratified drift with associated landforms such as kames, kame terraces, and eskers. The third group, pro-glacial deposits, consists of outwash plains and valley trains. Ground moraine, lateral moraine, and drumlinoid ridges were formed by the actively flowing glacial ice during the advance of the glacier, while the hummocky stagnation drift, the ice-contact stratified drift, pro-glacial deposits and part of the ground moraine were deposited during the deglaciation of the area.

These glacial deposits occur eight or more miles behind the Wisconsinan terminal moraine and represent the deposits of final deglaciation of the area. No evidence of pre-Wisconsinan glacial drift was found in the area. It was not possible to establish exact boundaries between particular genetic groups because the transitions between glacial and deglacial processes is gradational. The delineation of the groups was done mainly on topographic form.

UNSTRATIFIED DRIFT

Ground Moraine

Ground moraine occurs throughout the mapped area. In this report a cover of till is mapped as ground moraine only when the thickness of the till is three or more feet. Ground moraine may be represented either by topographically insignificant sheet-like cover or by undulating (swell and swale) morphology. Both of these types lack any alignment of their form. The local relief of the sheet-like ground moraine is very low and usually does not exceed 3 to 6 feet. The ground moraine cover is strongly controlled by the pre-glacial topography. The average relief of the undulating ground moraine is 9 to 15 feet. The thickness of the till varies from 3 to 48 feet with an average thickness of 10 to 19 feet. The thicker till deposits occur in bedrock depressions. The Paradise Creek valley is an example of a till-filled pre-glacial valley. Several exposures of the till occur along Paradise Creek near Henryville.

Very limited exposures of the ground moraine till restrict exact knowledge of its thickness and the indicated thicknesses are mostly inferred from field observations.

The ground moraine is frequently broken by hills and ridges of protruding bedrock and locally derived material is predominant in the till. This close relationship between till and bedrock may have resulted in mapping of some deposits as glacial till which are actually colluvium. Such colluvial deposits should be classified as a rubble mantle which originated by frost action during deglaciation of the region. The limited number of exposures prevents close observation of the deposits. These

materials could also have been disturbed by the weathering processes during deglaciation and post-glacial weathering.

Hummocky Stagnation Drift

Hummocky stagnation drift is formed during stagnation of glacial ice and displays characteristic "knob and kettle" topography composed of irregular hummocks, kettles and ridges without any prominent trend. The drift material comprises mainly till with some poorly defined glaciofluvial deposits. The local relief of this drift is 16 to 32 feet, with variations in the size, height and shape of each particular hill. In the vicinity of Analomink Lake where hummocky drift covers more than a square mile, there is a notable absence of an integrated drainage. Analomink Lake itself; and several other depressions presently containing peat, were originally glacial kettle holes probably formed by melting of buried ice blocks. The bulk of drift forming the hummocky moraine in the vicinity of Analomink Lake filled the pre-glacial valley of Brodhead Creek and forced the drainage into the stream bed to the west.

The hummocky drift occurs mainly in the lower parts of the region at an average altitude range of 600 to 650 feet near Analomink Lake and 700 to 800 feet in the Brodhead Creek valley of the northern part of the quadrangle. A transition between till of the hummocky drift and ice-contact stratified drift was found in the eastern part of the hummocky drift near Analomink Lake.

It is suggested that the hummocky stagnation drift of the mapped area was formed as a final phase of wasting during deglaciation of the region, when ice blocks were isolated in the topographically lower parts of the area and gradually disintegrated. The position and altitude of the hummocky drift and its transitions into ice-contact drift support this suggestion. Hummocky stagnation drift is identical with the hummocky dead-ice moraine of Gravenor and Kupsch (1959).

Drumlinoid Till Ridges

Drumlinoid till ridges dominate mainly the uplands of the area and are most extensively developed in the area between the East Stroudsburg Reservoir, Monroe and Manzanedo Lakes. The surface of the ridges are usually very smooth. It is generally accepted that drumlins and drumlinoid forms are developed by actively flowing ice and that their shape offered minimum resistance to fluid or fluid-like substance flowing past them (Fling, 1957). The presence of the bedrock hills and strike ridges usually athwart the main trend of the streamlined landforms suggests that the sheet-like movement of the glacier was disrupted by these bedrock irregularities and that they contributed to the deposition of this type of moraine.

The elongation of the drumlinoid till ridges is parallel with most of the measured glacial striae and thus reflects the direction of active ice movement which was almost north-south in the north and central part of the quadrangle.

Only a few of the streamlined landforms have the well defined shape of typical drumlins with their dimensions averaging about 1 mile in length, 1600 to 1900 feet in width and 130 to 160 feet in height. Most of the drumlinoid till ridges are composed of series of ridges with intervening longitudinal depressions (Fig. 4 and 5).

Figure 4. Streamlined ridges of drumlinoid moraine near Wooddale.

Since the drumlinoid till ridges make oblique angles with bedrock ridges in the area, bedrock cores probably do not occur in the till ridges. Limited outcrop and water well information indicate that the drumlinoid till ridges are composed of till which averages 60 to 130 feet in thickness.

The drumlinoid till ridges are separated by trough-like longitudianal depressions. Their origin is also related to actively flowing ice and the irregularities of the underlying bedrock.

The trend of the drumlinoid till ridges and their intervening longitudinal depressions coincides with that of the two main drainage channels of the area, Brodhead and Marshall Creeks. This fact suggests the possibility of a relationship of the ridges to the pre-glacial drainage system

of the area. However, no other evidence to support this possibility is presently known.

The trough-like longitudinal depressions acted as melt-water channels during deglaciation when the uplands were the first areas freed of ice cover. The ice sheet gradually retreated from the uplands of the region and was finally confined to the lower parts of the land. Outwash gravel fills the upper part of one of these channels for a distance of 1.5 miles in the vicinity of Wooddale. Another conspicuous channel is the valley above and below the East Stroudsburg Reservoir, but little or no outwash gravel was deposited in this channel which is incised in till or bedrock. These channels, as well as the other longitudinal depressions

Figure 5. Drumlinoidal ridges immediately west of Lake Monroe.

which did not act as melt-water channels, are mostly covered by a veneer of modern alluvial deposits derived from erosion of the till. The long profile of these channels has a low gradient in the upper and central parts and a steep gradient at the lower end.

The features of the drumlinoid till ridges described above are in agreement with the description of drumlinoid moraine by Fulton (1967) and the occurrence of similar drumlinoid moraine was observed by Penck and Bruckner (1909). A drumlinoid till ridge forms a short distance behind the belt of maximum ice advance where the debris load becomes so great in comparison with the carrying power of the ice that some debris must

be deposited upon the ground beneath, probably by a plastering process suggested by Russell (1897).

Lateral and end moraine

During the earliest phases of deglaciation of the area the ice sheet gradually melted from the uplands and was confined to the lower parts of the region. An end moraine east of Beakleyville (the Beakleyville moraine) was deposited during this phase. Lateral moraines in form of longitudinal ridges about 12–15 feet high extend diagonally down the valley slope of Pine Mt. Run valley south of Manzanedo Lake. Well developed lateral moraine occurs in the northern part of the quadrangle along

Figure 6. Lateral moraine along the west side of the Brodhead Creek valley, north of the mouth of Pine Mountain Run.

the west side of Brodhead Creek (Figures 6 and 7). Erosional relics of lateral moraine occur frequently along Brodhead and Marshall Creeks as well as in Middle Smithfield Township where many sub-glacier drainage channels and the amount of outwash gravel suggest that an extensive body of ice occupied this area.

The end moraine that occurs east of Beakleyville is composed of a compound deposit and lies athwart the Beakleyville-Marshall Creek valley. Its northern part is formed by an oval kame with the long axis in a north-south direction at an altitude of 470 to 540 feet. The kame is cut along its west side by Sambo Creek. A group of kames of relatively low altitude

460 to 500 feet occur farther to the south. Rhythmites exposed in a borrow pit one half mile northeast of Beakleysville along the road between East Stroudsburg and East Stroudsburg Reservoir lie below the altitude of 480 feet and indicate local ponding in this area. The group of kames adjoins morainic topography where till partly covers the protruding hills of bedrock or forms constructional loops blocking the south part of the valley.

Topographically similar features were described in the southern part of western New York by MacClintock and Apfel (1944) as valley stopper (or valley choker) moraines.

Figure 7. Till exposed in lateral moraine along the west side of the Brodhead Creek valley north of the mouth of Pine Mountain Run.

The moraine complex originated at the front of an ice lobe which occupied the Beakleyville-Marshalls Creek valley. This valley, in contrast to the Brodhead Creek valley, did not furnish sufficient gradient for movement of the ice lobe.

The Beakleyville moraine is broken by two gaps marking the position of melt-water channels. An extensive outwash plain was formed at the front of this moraine and is presently represented by a few terraces with the upper surface at 460 to 480 feet altitude. The outwash plain was incised by stream erosion associated with later deglaciation.

ICE-CONTACT STRATIFIED DRIFT

The accumulations of the ice-contact stratified drift in the mapped area occur as kames, kame terraces, and eskers. Their deposition was presumably related to the stagnation and melting of the glacial ice during deglaciation and usually occurred in its marginal areas. During deglaciation the glacial ice was confined to the lower parts of the area and its wasting was controlled by the bedrock topography. The succession of ice-contact sequences in the area indicates the various deglaciation events and their relative positions. Thus, as the ice melted in a north or northeast direction, the oldest and also the most extensive ice-contact deposits were developed in the southern part of the quadrangle in the vicinity of East Stroudsburg.

Kames and Kame Terraces

The distinction between kames and kame terraces is based on their morphologic differences. Kame terraces have a characteristic flat upper surface and were deposited by streams flowing between a glacier and an adjacent valley wall. Kames usually occur as cone shaped mounds in groups with a characteristic varying local relief of "kame and kettle" topography and were deposited in holes or depressions within the ice body.

Limited observations in a few sand pits indicate that the internal structure of kame deposits consists mainly of stratified gravel and sand with abrupt changes in grain size. Masses of till occur frequently in the gravel and some kames are veneered with a layer of till. The kame terrace deposits are similar in structure to fluviatile deposits, but frequent occurrences of deformed gravel (ice contact structure) indicates the former presence of a nearby mass of ice.

The kames of the area occur in the valleys with only a few isolated kames found at higher altitudes. One of these occurs along Michael Creek 2 miles northeast of Analomink at an altitude of 800 to 900 feet, while a more extensive kame occurs in Middle Smithfield Township at an altitude of 960 to 1000 feet.

Several kames were deposited in the valley of Flaglar Run in the west part of the quadrangle. A sand pit opened in one of the kames exposes 30 feet of gravel and sand. The deposit is very poorly sorted and stratified, and predominant clasts are in the medium gravel size. The kames in the south part of the valley have an altitude of about 520 feet at their base and 560 to 580 feet at their tops. Kames in the Big Meadow Run valley to the west have almost the same altitude. To the north Flaglar Run valley is covered by till for a distance of 0.5 mile before the valley broadens to over 700 feet in width where it is filled with ice-contact stratified gravel. This deposit is characterized by "kame and kettle" topography

with relatively low relief of 6 to 12 feet and it is often broken by protrusions of rounded bedrock hills. A sand pit located at the northeastern end of this deposit exposes about 80 feet of stratified drift. The lower part is formed by well stratified sand with an almost uniform steep angle (average: 25°) northwest dip of forest beds. The upper part is formed by almost unstratified, rounded and slightly sorted gravel whose cobbles average about 10 to 15 cm in diameter. This valley fill probably resulted from the wasting of glacial ice which was situated on the southeastern margin of the valley and discharged material that was deposited in a series of fans between the ice on the south and the steep valley walls of the Mahantango Formation of the northwestern side. Part of the discharge material was probably deposited on the surface of the ice confined in this valley and its melting away resulted in hummocks and closed depressions with low local relief. This type of morphology occurs in the central part of the valley about 1 mile northwest of Mt. Zion. The term of hummocky gravel was applied to similar deposits by Fulton (1967), but in this report they are termed kame deposit.

An extensive kame terrace was deposited on the west bank of Brodhead Creek west of East Stroudsburg. The flat topped surface is at an altitude of 480 feet. The internal structure and deformation of the stratified materials are exposed in a sand pit near Stroudsburg. An isolated kame at an altitude of 480 to 540 feet lies adjacent to the kame terrace southwest of Boise School. To the north and northeast of Boise School the kame terrace gradually grades into a complex of kames with a gradual northward decrease in the altitude and local relief. A longitudinal bedrock hill covered by till extends northward from Boise School. This hill was probably free of ice while the kame terrace deposits accumulated in the surrounding area. The ice was probably standing in the position which presently is the broad valley of Brodhead Creek.

Extensive kames and kame terraces mapped in the northern part of Broadhead Creek border outwash plains and hummocky moraine which formed in front of the ice during the younger of the two major still-stands during the deglaciation of the area. The altitude of the kame deposits ranges from 680 to 720 feet.

The disintegration of the ice confined to the valley of Paradise Creek in the vicinity of Henryville resulted in the deposition of a kame and kame terrace.

There is an obvious difference in the development of the upper and lower parts of Marshall Creek. The upper part acted as a melt-water channel during the deglaciation, while the lower part was filled with kames and kame terraces. The divide lies south of Marshall Creek borough. A large kame fills the creek just south of the divide and has an altitude of 480 to 500 feet. Several less extensive kames are developed to

the south along the creek. A kame terrace on the west bank of the creek one mile to the east of the Franklin Hill Cemetery has its upper surface at an altitude of 420 feet. The valley in the vicinity of North Water Gap is filled by a thick kame deposit. This area was mapped and described by Epstein (1969).

Eskers

Two eskers occur in the mapped area: one in Middle Smithfield Township 1½ miles northeast of Wooddale, the other near North Water Gap. These eskers are long, narrow, sinuous, ice-contact ridges composed chiefly of stratified drift. They formed during deglaciation of the region.

The esker in Middle Smithfield Township occurs at an altitude of 900 feet and is about 600 feet long and 40 feet high with a gradient toward the Marshall Creek valley bottom. Many carved channels in till suggest a widespread sub-ice drainage for which the valley of present Marshall Creek acted as a main drainage channel. A borrow pit in the southern part of the esker exposes stratified gravelly sand with stratification parallel to the slopes of the esker probably as a result of slope sliding during melting of the retaining ice walls.

The esker that occurs in the vicinity of North Water Gap on the left bank of Marshall Creek is an inwash esker and was mapped and described by Epstein (1967).

PROGLACIAL DEPOSITS

The proglacial deposits of the area consist of stratified drift deposited beyond the limits of the glacial ice by melt-waters during the deglaciation of the region. The outwash plains adjoining the original ice marginal deposits and their down valley continuation, valley trains, are characterized by the flatness of the upper surface which has a relief of 3 to 6 feet and is internally well stratified. The sediment exhibits a high degree of sorting, an absence of silt and clay and a higher degree of pebble roundness than most other deposits.

The proglacial deposits of the mapped area occur in the valleys of Brodhead and Marshall Creeks (valley train), near Marshall Creek Borough (deltaic terrace) and near Wooddale (outwash plain).

Two terraces occur along Brodhead Creek (Figure 8). The top of the higher terrace is 12 to 18 feet above the present stream bed and presumably represents the original level of valley fill. The top of the lower terrace which is covered by brown silty and clayey alluvial sand, is 6 to 10 feet above the present stream bed and probably represents an erosional surface cut into the original valley fill. The gradient of these terraces is parallel to that of the present stream bed.

Figure 8. Two terrace levels of valley train along Brodhead Creek, near its confluence with Paradise Creek.

The valley fill was deposited during an extensive still-stand and stagnation of ice which was confined to the Pine Mountain Run valley and the northern part of the Brodhead Creek valley. The outwash plains are here adjacent to hummocky moraine and kames. The surface of the higher terrace has an observable braided stream pattern and occurs at an altitude of 680 to 700 feet. This level is subject to flooding during the most severe circumstances while the lower terrace level is probably flooded almost yearly.

These two terrace levels are also developed in the vicinity of East Stroudsburg at an altitude of 460 to 440 feet and part of the city itself is built on them. The relatively older kame deposits (see ice-contact deposits) are generally of higher altitude than the valley train terraces and were dissected by stream erosion associated with the development of the Brodhead Creek valley train. The outwash plain in front of the Beakleyville moraine was also subjected to dissection at this time. The relief created by this dissection is about 12 feet.

The Marshall Creek valley train and the Beakleyville-Marshalls Creek valley are closely related in origin. During the retreat of ice from the Beakleyville-Marshall Creek valley, a valley stopper moraine blocked the west end of the valley thus creating a dam for a lake which developed between the moraine and the front of the melting ice. This lake was partly filled by material discharged during the recession of the ice not only from

the Beakleyville-Marshall Creek valley, but also from the Marshall Creek valley.

Deglaciation of Middle Smithfield Township resulted in the deposition of valley train in Marshall Creek Valley (Figure 9) and a deltaic terrace (after Fulton, 1967) in the lake at the mouth of the valley (Figures 10 and 11). During the wasting of the ice, numerous blocks of ice were isolated and covered with debris. The eventual melting of base blocks resulted in collapse of the overlying debris and creation of kettle holes. The largest kettle occurs in the northern part of the deltaic terrace and has a diameter of 300 feet. The surface of the deltaic terrace slopes gently to the southwest and has an altitude of 468 to 500 feet. The surface of the valley train terrace slopes from an altitude of 700 to 540 feet.

A water well drilled in the deltaic terrace north of Graigs Meadows penetrated 60 feet of gravelly sand and sandy gravel before bedrock was reached.

The valley train fill and the deltaic terrace have been incised by post-glacial erosion to the depth of 9 to 10 feet.

LACUSTRINE DEPOSITS

The pronounced relief of most of the quadrangle probably resulted in the paucity of lacustrine deposits in the area.

A glacial lake was formed during deglaciation in the broad Beakleyville-Marshall Creek valley between the Beakleyville moraine at its southeast side and the ice-margin of the northeastward retreating glacier. The lake was partly filled by the melting of an ice body confined to the broad valley and partly by material discharged during the ice retreat in Marshall Creek valley. The deltaic terrace was formed of gravelly sand dumped into the lake. The deposit is about 60 feet thick, but no other information about this deposit is available. The rest of broad valley is covered by alluvial deposits.

A few inches of lacustrine deposits underlying peat were exposed in an excavation near Birch Wood and they are described in the section on peat bogs.

Rhythmically stratified silt and clay deposits are exposed in a borrow pit one half mile northeast of Beakleyville. Their formation resulted from local ponding during the development of the Beakleyville moraine.

LITHOLOGY OF THE GLACIAL DRIFT

The character of the glacial drift in the East Stroudsburg Quadrangle is closely related to the underlying bedrock. The material was derived mainly from clastic deposits of the Devonian Catskill Formation and a high content of sand in the drift reflects the frequent occurrence of sandstones in the bedrock sequence.

Figure 9. The valley train surface in Marshall Creek valley north of Marshall Falls.

Figure 10. Kettled deltaic terrace underlying a golf course at west edge of Marshall Creek Borough.

Figure 11. Kettled deltaic terrace underlying a golf course at west edge of Marshall Creek Borough.

The till is a mixture of rock fragments set in a clay-silt-sand matrix, and is characteristically a clayey sandy silt to silty sand (classification of Shepard, 1954). On the whole the sand content increases toward the north in the area although local variations in the size distribution are frequent. The average content of sand ranges from 75 to 85 percent at some sites, to 90 to 95 percent in the northern part of quadrangle. The sand is composed predominantly of quartz grains with only a trace of feldspar. Most of the samples do not react to dilute hydrochloric acid. This absence of carbonate is in agreement with the provenance of the till. Only a few sites in the southern part of the area where the underlying bedrock is limestone does the till show any carbonate beneath the B horizon of a soil profile.

The compactness and plasticitity of till vary according to the grain size distribution of till. The till is mostly loose to very moderately compact in the area. Only in a few exposures in the western part of East Stroudsburg does the till have a higher clay content and a resultant massive and compact structure. Most of the till exposures do not exceed a few feet in thickness and are usually very close to the surface, thus increasing the probability that their original structure has been disturbed. A till exposed in the road cut in the Pine Mountain Run valley is formed of moderate yellowish-brown (10YR 5/4) very fine-grained silty sand with rock fragments with an average size of 2 to 3 inches. A few boulders, not exceeding

15 inches in diameter, are also exposed in the cut. Sand grains are almost entirely quartz. Green and red fine grained sandstones of the Catskill Formation comprise all the clasts present. About 40 percent of the clasts are striated. The deposit is rather loose, only lenses of more silty till appearing to be compacted. No stratification of till was observed, but there is apparent organization of the clasts in the orientation of their longer axes. In general, this direction is parallel with the trend of striae of the area.

Southwest of Mt. Zion Borough a pale yellowish-brown (10YR 6/2) sandy till was exposed in the road cut. Rock fragments are mostly green and red Catskill sandstones (80 percent), but dark gray siltstones and shales of the Mahantango Formation also are present (20 percent). About 70 percent of clasts are striated. The deposit is loose to moderately compact, unsorted and possesses a chaotic structure.

A very well developed platy structure of silty sand in a kame is exposed in the borrow pit one half mile northeast of Beakleyville. The long axes of plates are parallel to the surface. This feature has been described as a cleavage or horizontal fissility by Flint (1947) and is attributed to the orientation of mineral grains by the weight of an overlying ice. The development of this platy structure in the B horizon of a Podzol (Spodosol) is more probably attributed to climatic conditions after the ice retreat, possibly a process of an annual freezing of the ground.

ANALYSES

Fifteen representative samples (Table 1) were collected from glacial deposits in the East Stroudsburg Quadrangle. Particles over 10 cm in diameter were not collected. The number of samples is not sufficient for any detailed evaluation, but the results give some indication as to the character of the glacial deposits.

Analyses were made of the following: (1) particle size distribution of the total sample, (2) distribution of lithologies in 3 selected size fractions and (3) particle shape in terms of roundness and flatness.

All samples were sieved by hand through a set of 7 sieves into 8 size classes ranging from less than 0.5 mm to more than 64 mm and the weight percentage of each fraction was calculated. The average sample weight was 20 pounds. Histograms of the size distribution in each sample are shown in Figure 12.

An analysis of the composition of particles comprising the glacial drift in the East Stroudsburg Quadrangle revealed the following 9 lithic groups:

1. Very fine-grained sandstone, light olive gray (5Y 5/2): Catskill and Trimmers Rock Formations
2. Fine-grained sandstone, medium gray N 5, greenish gray (5GY 6/1), light olive gray (5Y 5/2): Catskill Formation

3. Siltstone, pale olive (10Y 6/2), light olive gray (5Y 6/1), medium gray (N 5): Mahantango, Trimmers Rock and Catskill Formations
4. Shales, pale olive (10Y 6/2), medium gray (N 4): Mahantango Formation
5. Very fine-grained sandstone, grayish red (10R 4/2): Catskill Formation
6. Siltstone, grayish red (10R 4/2): Catskill Formation
7. Fine-grained sandstone, moderate brown (5YR 6/2): Catskill Formation (?)
8. Very coarse-grained sandstone, pale yellowish brown (10YR 6/2): Catskill Formation
9. Cherty limestone: Buttermilk Falls Limestone

Table 1. *Details of samples collected from glacial drift in the East Stroudsburg Quadrangle.*

Sample	Location	Type of Exposure	Depth from surface in feet	Lithology	Type of Deposit
S 1	1 mi. west Marshall Creek	excavation	3.3	gravel	deltaic terrace
S 2	1 mi. west Marshall Creek	excavation	6.6	gravel	deltaic terrace
S 3	1.5 mi. south Lake Monroe	borrow pit	6.6	gravel	outwash plain
S 4	East Stroud. Reservoir	road cut	1.6	till	ground moraine
S 5	Wooddale	road cut	1.0	till	ground moraine
S 6	2 mi. sw Mt. Zion	borrow pit	19.7	gravel	kame
S 7	0.5 mi. west Boise School	borrow pit	8.3	gravel	kame terrace
S 8	Brodhead	road cut	8.3	gravel	kame
S 9	Henryville	rail-road cut	5.0	till	ground moraine
S 10	0.3 mi. west Henryville	borrow pit	5.5	till	ground moraine
S 11	0.5 mi. south Pipher Airport	road cut	2.2	till	ground moraine
S 12	Pipher Airport	excavation	5.0	gravel	outwash plain
S 13	0.7 mi. south North Wind Gap	borrow pit	14.8	gravel	kame
S 14	Lake Monroe	excavation	2.0	gravel	outwash plain
S 15	Birch Wood	excavation	5.0	till	ground moraine

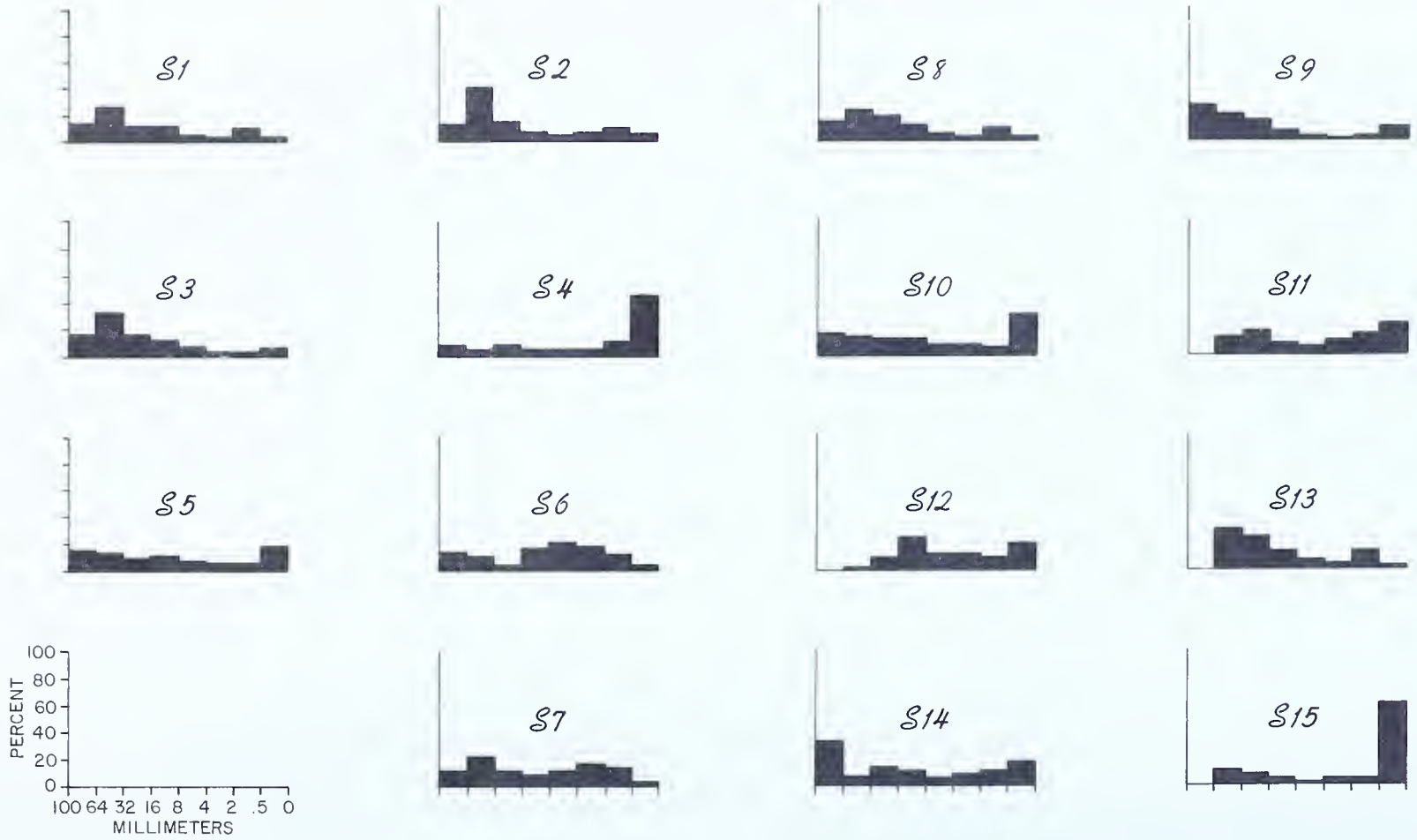

Figure 12. Size distribution histograms of glacial drift samples from the East Stroudsburg Quadrangle. See Table 1 for sample locations.

Table 2. *Distribution of different lithologies in selected size fractions of glacial drift from the East Stroudsburg Quadrangle.*

1* Sample	2* Size Fraction	3* Lithic Group 1	2	3	4	5	6	7	8	9
S 1	f.2	57.8	7.3	11.1	22.2	3.7	—	—	3.7	—
	f.3	54.0	—	19.2	16.9	5.5	4.5	—	—	—
	f.4	70.0	2.0	2.0	16.0	—	10.0	—	—	—
S 3	f.2	57.5	36.5	—	—	6.0	—	—	—	—
	f.3	79.0	7.4	4.2	3.2	2.8	—	2.8	0.6	—
	f.4	75.0	8.0	5.0	2.5	3.5	—	4.0	—	—
S 4	f.2	75.0	—	25.0	—	—	—	—	—	—
	f.3	75.0	20.0	5.0	—	—	—	—	—	—
	f.4	64.0	10.0	6.0	2.0	3.0	—	—	—	—
S 5	f.2	33.4	16.7	—	—	16.7	33.4	—	—	—
	f.3	11.5	47.0	—	—	11.5	29.0	—	—	—
	f.4	46.0	20.0	4.0	—	20.0	10.0	—	—	—
S 6	f.2	50.0	—	—	50.0	—	—	—	—	—
	f.3	8.7	13.0	—	74.0	5.6	—	—	—	—
	f.4	10.0	6.0	—	84.0	—	—	—	—	—
S 7	f.2	18.3	54.1	—	9.3	50.0	—	—	—	—
	f.3	62.0	11.6	10.0	6.7	3.3	5.5	1.4	—	—
	f.4	64.0	8.0	4.0	4.0	11.0	10.0	—	—	—
S 8	f.2	—	55.5	16.6	22.4	—	—	—	5.5	—
	f.3	49.0	18.0	11.7	2.6	10.4	5.2	1.3	2.6	—
	f.4	52.0	6.0	20.0	4.0	12.0	4.0	—	2.0	—
S 9	f.2	71.0	—	—	—	—	—	—	29.0	—
	f.3	64.0	9.6	—	—	—	7.3	—	4.8	—
	f.4	54.0	10.0	4.0	2.0	8.0	—	—	2.0	—
S 10	f.2	—	75.0	—	25.0	—	—	—	—	—
	f.3	14.2	43.0	19.0	9.5	14.2	—	—	—	—
	f.4	58.0	10.0	6.0	4.0	20.0	2.0	—	—	—
S 12	f.2	100.0	—	—	—	—	—	—	—	—
	f.3	52.0	12.0	16.5	13.1	2.0	4.4	—	—	—
	f.4	44.0	26.0	6.0	10.0	2.0	8.0	2.0	—	—
S 13	f.2	9.5	14.1	48.0	14.2	4.8	—	—	—	9.5
	f.3	15.5	3.4	52.0	26.0	3.1	—	—	—	—
	f.4	6.0	8.0	54.0	30.0	2.0	—	—	—	—
S 14	f.2	20.0	60.0	20.0	—	—	—	—	—	—
	f.3	44.0	27.0	9.6	—	7.8	11.6	—	—	—
	f.4	62.0	18.0	6.0	—	14.0	—	—	—	—
S 15	f.2	—	100.0	—	—	—	—	—	—	—
	f.3	62.0	15.5	—	3.8	15.5	3.0	—	—	—
	f.4	56.0	8.0	4.0	2.0	28.0	2.0	—	—	—

*1. See Table 1 for location of samples.

*2. Size fractions are: f.2 = 32 to 64 mm; f.3 = 16 to 32 mm, f.4 = 8 to 16 mm.

*3. See text for description of lithic groups.

The particles of each group were counted separately in three size fractions and the results are presented in Table 2.

Very fine-grained (1) and fine-grained (2) sandstones of the Catskill Formation are the predominant rock types in the till. A few fragments of cherty limestone (9) occur in till in the southeastern part of the quadrangle where the Buttermilk Falls Limestone outcrops, while very-coarse-grained sandstones (8) of the Catskill Formation predominate in the till of the northern part of the area. A southward decrease in the amount of very coarse grained sandstone (8) occurs in gravel of the Brodhead Creek valley train. No igneous or metamorphic clasts have been found in the area.

Table 3. *The average coefficient of flatness for particles in nine lithic groups from two size fractions of samples of glacial drift in the East Stroudsburg Quadrangle.*

1* Sample	2* Size Fraction	3* Lithic Group 1	2	3	4	5	6	7	8	9
S 1	f.2	4.8	5.4	6.0	5.4	8.7	—	—	—	—
	f.3	4.6	—	5.3	8.3	7.7	—	—	—	—
S 3	f.2	4.0	—	2.2	—	10.0	—	—	—	—
	f.3	5.5	4.3	4.0	7.0	8.0	—	—	—	—
S 4	f.2	5.0	—	—	—	—	—	—	—	—
	f.3	4.5	4.0	—	—	—	—	—	—	—
S 5	f.2	5.5	2.3	—	—	4.2	—	—	—	—
S 6	f.2	4.7	—	3.5	—	—	—	—	—	—
	f.3	3.7	4.3	—	4.2	5.0	—	—	—	—
S 7	f.2	2.0	3.3	—	—	1.5	—	—	—	—
	f.3	3.4	2.8	5.2	5.7	6.8	3.9	—	—	—
S 8	f.2	—	4.7	9.0	9.2	—	—	1.5	—	—
	f.3	5.0	3.7	6.2	8.1	4.2	6.6	—	2.3	—
S 9	f.2	1.3	—	—	—	—	—	—	1.5	—
	f.3	4.3	2.2	—	—	3.5	—	—	—	—
S 10	f.2	—	2.2	—	—	—	—	—	—	—
	f.3	3.3	4.2	3.8	6.8	3.1	—	—	—	—
S 12	f.3	4.0	3.4	3.5	6.8	4.9	—	—	—	—
S 13	f.2	6.6	3.4	1.8	6.6	2.1	—	—	—	3.6
	f.3	3.0	4.1	3.7	6.8	3.5	—	—	—	—
S 14	f.2	2.6	5.2	—	—	—	—	—	—	—
	f.3	5.0	3.7	4.4	—	4.3	4.2	—	—	—

*1. See Table 1 for location of samples.
*2. Size fractions are: f.2 = 32 to 64 mm, f.3 = 16 to 32 mm.
*3. See text for description of lithic groups.

Distinction between pebbles derived from different members of the Catskill and Trimmers Rock Formations was not possible. Likewise, a distinction between pebbles of the Mahantango and Marcellus Shales was not possible, but most shale pebbles were probably derived from the Mahantango.

The distribution of particular lithic types relative to the bedrock of the area (Plate 1) indicates that the direction of pebble transportation was generally to the south.

Particle shape for pebbles from the glacial drift is measured by the morphometrical methods of Cailleux (1947). The coefficients are deter-

Table 4. *The average coefficient of roundness for particles in nine lithic groups from two size fractions of samples of glacial drift in the East Stroudsburg Quadrangle.*

1* Sample	2* Size Fraction	3* Lithic Group 1	2	3	4	5	6	7	8	9
S 1	f.2	—	555	308	145	103	—	—	—	—
	f.3	315	340	340	75	358	330	—	—	—
S 3	f.2	232	510	—	—	350	—	—	—	—
	f.2	230	375	416	177	347	—	—	—	—
S 4	f.2	185	—	—	—	—	—	—	—	—
	f.3	55	150	—	—	—	—	—	—	—
S 5	f.2	150	470	—	—	50	—	—	—	—
S 6	f.2	155	—	180	—	—	—	—	—	—
	f.3	100	175	—	230	312	—	—	—	—
S 7	f.2	312	305	—	—	255	—	—	—	—
	f.3	400	290	250	450	300	310	—	—	—
S 8	f.2	—	333	303	—	—	—	306	—	—
	f.3	360	455	205	280	325	325	—	—	330
S 9	f.2	135	—	—	—	—	—	—	382	—
	f.3	230	166	—	—	100	—	—	—	—
S 10	f.2	—	152	—	—	—	—	—	—	—
	f.3	110	140	50	75	75	—	—	—	—
S 11	f.2	390	—	—	—	—	—	—	—	—
	f.3	350	285	300	305	360	—	—	—	—
S 13	f.2	395	590	500	280	280	—	—	—	210
	f.3	300	380	365	290	360	—	—	—	—
S 14	f.2	280	—	303	—	—	—	—	—	—
	f.3	228	258	311	—	291	176	—	—	—
S 15	f.2	100	120	55	—	—	—	—	—	—
	f.3	120	—	—	—	—	120	—	—	—

*1. See Table 1 for location of samples.
*2. Size fractions are: f.2 = 32 to 64 mm, f.13 = 16 to 32 mm.
*3. See text for description of lithic groups.

mined by measuring single axes and diameter of the minimum rounding. Formula (a+b)/2c applies for flatness; and formula (2r.1000)/a for roundness; *a*, *b* and *c* are respectively the largest, intermediate and smallest axes of clasts, *r* is a diameter of minimum rounding. This diameter is the diameter of the largest circle which can be placed in the smallest corner of a pebble viewed parallel to the c (smallest) axis. The clasts of the IX lithic groups were measured separately for two size fractions in each sample and the results are presented in Table 3 and Table 4. The coefficient of roundness of angular and sub-angular clasts of till ranges mainly between 55 and 230. Some clasts have a coefficient of roundness less than 55, but they are usually fragments of shale transported only a short distance. Several clasts from till possess a high degree of rounding and their coefficient is that of water-laid deposits. This coefficient averages about 300-400 and particles with a high degree of rounding have a coefficient more than 600.

The occurrence of many particles with a very low degree of rounding and local lithologies indicates that the local bedrock was a major source of the glacial drift.

RECENT DEPOSITS

This group comprises the deposits formed after the melting of glacial ice from the region and includes alluvial deposits, colluvium, peat bogs, and soils.

ALLUVIUM

Both stream alluvium and alluvial fans occur in the mapped area. The alluvium is stratified sand and sandy loam which overlies the floodplain of the present streams. The most extensive alluvial cover is along Brodhead Creek, especially in the vicinity of East Stroudsburg where the flood plain is almost a mile wide. The alluvium was deposited during repeated floodings of the alluvial plain and the thickness usually does not exceed 4 feet. An alluvial plain is also developed along other streams such as Paradise and Marshall Creeks and their tributaries. Along the tributaries the alluvium is accumulated at the head and middle parts where the long profile has a very low gradient. The oversteepened lower part of the tributary has no alluvium and usually terminates in an alluvial fan. A wide spread alluvial deposit occurs on the very flat Beakleyville-Marshall Creek valley and is intergrading with alluvial peat deposits near Pipher Airport.

Several alluvial fans are developed along the Brodhead and Marshall Creek valleys at the mouth of oversteepened tributaries. The cone-shaped form with apices of the fan in the mouth of the tributary valley is dis-

tinctive from the flat topped terraces of the outwash fill upon which most of them are developed. These fans were formed mainly during the post-glacial period and the degree of dissection of the fans is a factor in determining their relative age.

One of the largest alluvial fans is a mile south of Analomink. A road cut in this form is developed at the terminus of the Sambo Creek Valley and covers part of the outwash plain of the Beakleyville-Marshall moraine.

COLLUVIUM

Weathering of the surficial deposits and bedrock has occurred since the area was free of ice. Frost action occurred on the uplands during deglaciation when the ice was confined to the lower parts of the region. It resulted in the formation and accumulation of an angular regolith which has been partly transported down the slopes by mass wasting. Well developed cleavage and bedding planes in the Mahantango Formation were planes of weakness utilized by frost action to form accumulations of shale-chip rubble. The thickness of the deposit in the mapped area usually does not exceed a few feet.

Colluvium was not mapped as a unit because of its small thickness.

PEAT BOGS

The development of peat bogs in the mapped area is closely related to the formation of undrained depressions in the glacial drift through modification of pre-glacial drainage by damming of valleys and plucking of the bedrock. Several dams built for fresh water reservoirs or for recreation purposes in the upland valleys north of East Stroudsburg have resulted in the accumulation of peat in the upper parts of these ponds.

Most of the peat bogs occur in the wooded uplands of the area. The covering vegetation of a few bogs of the area such as Ivan Swamp and the depression in the hummocky moraine south of Analomink Lake consists only of reeds and sedges. This type of peat bog may be classified as a low-moor or sedge-reeds peat bog, which is one of the four major types of peat bogs (Waksman, 1942). The only typical forest peat bog occurs in the forested area of Middle Smithfield Township in the northern part of the quadrangle.

Most of the peat bogs are covered by reeds and sedges in the middle and the most moist part of the bog and gradually grade into low shrubs and trees at their margins. The trees and shrubs are mostly deciduous, but laurel and rhododendron also occur frequently. This transitional type of peat bog is the most frequently developed type in the area and was found in the vicinity of the Monroe Lake, Analomink Lake, East Stroudsburg Reservoir, Craigs Meadow, and Pipher Airport.

A peat bog near the recreation center of Birch Wood (2 miles west of Analomink Lake) was recently drained and partly cultivated. The excavation exposed the following profile:

Depth in feet

0.0-2.7 Black reed and sedge peat with wood.
2.7-4.9 Brownish, partly decomposed reed and sedge peat with wood.
4.9-5.6 Gray silt and clay with fragments of sandstone.
5.6-7.2 Rhythmically laminated gray and grayish brown sand, silt, and clay; the content of clay increases toward the top of the strata (lacustrine deposits).
7.2-13.1 Brownish gray sandy till.

The thickness of the peat is not known in any other peat bog. None of the bogs is presently mined, although mining of peat from a bog near Franklin Hill Cemetery (East Stroudsburg Township) was recently stopped.

SOILS

The Podzolic soils (U. S. Dept. Agriculture, 1938) are the great soil group most extensively developed in the quadrangle. These soils have minor variabilities in development which are related to the texture and lithology of the parent material and to their topographic position. Major differences in drainage conditions of the soil profile caused the development of other less extensive soils in the area. The soils range from a very well-drained Podzolic soil to poorly and very poorly drained low humic gley and humic gley soils to alluvial soils. Lithosol and Regosol, soils with poorly developed soil profiles, also occur in the area.

The wide-spread Podzolic soils are developed on all types of the glacial deposits. A well developed profile of this soil formed on the outwash is exposed in a sand pit near a drive-in theater north of East Stroudsburg and displays the following profile:

Horizon	*Description*	*Depth in Inches*
A_0	Grayish black (N2) layer of partly decomposed organic matter.	0.00-7.50
A_1	Black (N1) completely decomposed mineralized humus with sand.	7.50-17.50
A_2	Gray (N6) leached horizon, clayey sand.	17.50-42.50
B	Yellowish brown (10YR 5/4) illuvial horizon with an increased clay content, coatings of an accumulated clay and iron and alumina compounds, clayey sand.	42.50-118.00
C	Parent material, grayish brown (5YR 4/1 sand	118.00-500.00

The base of the B horizon is not always clear since the transition into parent material is usually gradual. Sometimes the B horizon of the Podzolic soil is developed to more than 3 feet in thickness on the glacial drift.

The low humic soils and humic soils belong to the poorly drained soil group. Their soil profile is developed under the influence of a fluctuating ground water table with water present during most of the soil forming process. Its characteristic features are a gray or black surface layer containing accumulated organic matter and an underlying grayish, mottled horizon developed under anaerobic conditions. These soils are developed on till and stratified drift in very poorly drained areas. An exposure of a typical low humic soil near Boise School had a grayish surface layer 50 inches thick and an underlying gray and brownish mottled horizon 215 inches thick.

Regosols are developed on recent sand and gravel deposits usually forming alluvial fans. A slightly brownish gray or brown A horizon is weakly developed in these soils.

The soils in the mapped area have all developed since the Wisconsinan glaciation. No paleosol in the sense of Hunt and Sokoloff (1950) was found in the area. All soils developed before the glaciation were apparently removed by glacial erosion or buried beneath their deposits.

The lack of calcium carbonate in the glacial till of the area probably results from the absence of carbonate rocks in the bedrock rather than weathering of the till.

ECONOMIC PRODUCTS

SAND AND GRAVEL

The valuable sources of the sorted sand and gravel are represented by ice-contact and pro-glacial deposits of the quadrangle. They occur mainly in the Brodhead and Marshall Creek valleys, but several kames also fill the valley of Flaglar Run and the valley north of Mt. Zion in the southwest part of the area. A few isolated kames occur in the uplands of the quadrangle southwest and northwest of Woodale. The most extensive accumulations of the stratified drift occur in close proximity to East Stroudsburg and much of it underlies the developed city.

The thickness of ice-contact and pro-glacial deposits varies from a few feet of irregulary distributed accumulations of sand and gravel to the tens of feet of stratified drift of kame terrace in the northwestern part of East Stroudsburg. Only a very small number of excavations and borrow pits are presently open in the area and data on the thickness of the deposits are based mainly on field observations.

The thickest and most extensive sand and gravel deposit of the area is a kame terrace underlying the recently developed northwestern part of East Stroudsburg. The thickness of the drift varies from 20 to 50 feet with a probable decrease to the west. Stratified and sorted material in the deposit ranges from bouldery gravel to medium- and fine-grained

sand. The lithologic analysis of Sample 7 (Tables 1 & 2) taken from a borrow pit west of Boise School shows the predominance of Catskill sandstones and less than 10 percent of Mahantango shales.

A borrow pit located in one of the kames of the Flaglar Run Valley exposes very poorly sorted and stratified sand and gravel 30 feet thick. The predominant clasts are in the medium gravel size and the prevailing pebble is derived from the Mahantango shales (Sample 6, Table 2).

A sand pit presently open in an extensive kame located 1.5 miles northeast of Mt. Zion exposes about 80 feet of sand and gravel. The lower part of the deposit is formed by well stratified, sorted, medium- and coarse-grained sand with uniform steep angle of foreset beds. The upper part of the kame is formed by almost unstratified, rounded and slightly sorted gravel whose cobbles average about 10 to 15 cm in diameter. The nearby Mahantango supplied part of the material, but Catskill sandstones are the predominant lithologies.

In the eastern part of the quadrangle south of North Water Gap a large borrow pit is open in a thick kame. The thickness of stratified drift is here 30 to 60 feet, and the deposit is characterized by abrupt changes in size distribution ranging from bouldery gravel to coarse- and medium-grained sand. Lithologic analysis indicates the presence of about 50 percent of siltstones of the Mahantango, Trimmers Rock and Catskill Formations and less than 10 percent of cherty limestone of Buttermilk Falls Limestone (Sample 13, Table 2).

Two terraces of valley train bordering Brodhead and Marshall Creeks contain accumulations of well sorted and stratified gravel. They are incised by post-glacial erosion to a depth of about 9 feet. These terraces are subject to flooding and the lower terrace is mostly covered by alluvium. The exact thickness of these deposits is not known although a few water wells drilled in the outwash fill of the broad valley between Beakleyville and Marshall Creek penetrated 20 to 40 feet of gravelly sand and sandy gravel before bedrock was reached. The lithologic analysis of Sample 1 and 2 (Table 2) taken from an excavation in the deltaic terrace near Marshall Creek indicates the presence of about 20 percent of Mahantango shale and 80 percent of sandstones and siltstones of Catskill and Trimmers Rock Formations.

TILL

Glacial till is the dominant type of glacial drift of the East Stroudsburg Quadrangle. The predominantly sandy character of the till and lithology of the clasts may allow some use of this material as road fill despite its heterogeneity and higher clay content. Catskill sandstones are the predominant lithologies of the till clasts (Table 2).

PEAT BOGS

Several peat bogs occur throughout the mapped area mostly in its uplands. The peat bogs have rather small areal extent suggesting a limited quantity of peat. The thickness of peat in any of the deposits is not known. At present no peat bog of the quadrangle is exploited since the mining of peat from the bog near Franklin Hill Cemetery east of East Stroudsburg was recently stopped. Any attempt at peat exploitation should be preceded by extensive exploration.

GROUND WATER

Recent information on ground water of the quadrangle is presented in Table 5. Although Lohman (1937, p. 173) indicates that some surficial material may yield appreciable quantities of water, available water well data indicate that all wells in the mapped area derive water suitable for domestic use from bedrock sources throughout the area.

FLAGSTONE

The Towamensing Member of the Catskill Formation is a potential source of flagstone. The sandstone tends to break into flaggy plates, has an attractive color and appears to be durable. This sandstone was quarried extensively on the west side of Brodhead Creek at Analomink many years ago, but was presumably used entirely for crushed rocks. Further investigation of the use potential of this sandstone may be warranted.

CRUSHED ROCK

The Towamensing Member of the Catskill Formation discussed above is also a potential source of crushed rock, although the flaggy tendency may limit its usefulness.

The undifferentiated Lower Devonian and Silurian limestones in the southeast part of the mapped area may be potential sources of crushed rock, but considerable exploration is required to prove their usefulness.

Table 5. *Water well data from drillers reports on wells drilled in the East Stroudsberg 7½′ Quadrangle since 1966. (Map unit symbols in italics are only probable identifications of source rock.)*

Map Unit	Driller's Lithology	Surficial Material	Depth to Bedrock (ft)	Depth of well (ft)	Depth to water bearing zones (ft)	Yield (GPM)	Static water level (ft)	Date Drilled	Location
Middle Smithfield Twp.									
Dcw	red shale green sandstone	—	89	135	100/125	11	63	5/14/68	Pocono Highland Estates 1 mi. N. of Wooddale
Dcw	gray rock	boulders	5	70	35/65	11	7	1/22/68	ditto
Dcw	red sandstone	gravel	30	75	42/60	19	15	1/1/66	Juniper St., Lake Monroe
Dcw	sandstone	gravel	14	83	22/40	8	20	7/18/66	Edelweiss St., Lake Monroe
Dcw	red sandstone	gravel	28	96	18/62	8	29	6/25/66	Aster St., Lake Monroe
Dcw	sandstone	gravel, clay	33	110	39/60	8	39	6/5/67	16 Pepper St., Lake Monroe
Dcw	sandstone	gravel	8	75	38/67	6	12	6/12/67	Lakeshore Dr., Lake Monroe
Dcw	sandstone	gravel	24	85	40/56	7	28	7/16/67	Opes St., Lake Monroe
Dcw	sandstone	gravel	18	80	30/39	10	24	7/12/67	Iaritol Rd., Lake Monroe
Dcw	red shale green coarse red (hard)	—	43	125	55/118	15	50	11/16/67	Pocono Highland Estates 1 mi. N. of Wooddale
Dcw	sandstone	loam	16	96	52/69	8	22	11/27/67	Lakeshore Drive, Lake Monroe
Dcw	sandstone	loam	19	69	40/65	5	30	11/20/67	Marshall Creek Rd. 6 mi. N. of Marshall Creek
Do-bf	limestone	clay	5	233	160/—	5	15	7/6/68	Coolbaugh Drive N. of Blue Ridge Inn

Dm	shale	sand gravel	10	75	35/65	7	10	7/15/67	Coolbaugh Drive near Heddys Lake View House
Dcw	soft brown coarse gr. coarse red hard green	—	20	135	52/83	10	40	5/6/68	Pocono Highland Estates 1 mi. N. of Wooddale
Dcw	hard green red	—	59	153	80/121	9	60	4/15/68	same
Stroud Twp.									
Dcw	sandstone limestone	over-burden	18	122	70/115	20	0	11/10/67	Wooddale
Dtr	shale limestone siltstone	sand	10	170	80/125	13	40	6/11/66	Twin Oak Rd. SE of Analomink
Dcw	sandstone	clay, loose formation	102	232	156/225	10	60	6/67	Analomink Lake
Dm	shale	—	59	130	64/105	10	15	9/7/67	North of Eagle Valley along #96
Smithfield Twp.									
Dmh	gray rock	sand, gravel boulders	1	135	114/121	30	22	4/4/68	N. of #402, E. off fire house, Marshall Creek
Dmh	gray rock	same	43	75	48/56	40	20	3/27/68	same
Dmh	slate	gravel	20	130	40/115	10	20	10/6/66	½ mi. NE of Pipher Airport
Dcw	red rock	over-burden	29	125	60/118	15	10	9/24/66	5 mi. N. of Marshall Creek
Do-bf	limestone	—	3	128	35/55	30	15	5/20/66	1 mi. E. of E. Stroudsburg on S. side of #209

Table 5. continued

Map Unit	Driller's Lithology	Surficial Material	Depth to Bedrock (ft)	Depth of well (ft)	Depth to water bearing zones (ft)	Yield (GPM)	Static water level (ft)	Date Drilled	Location
Dmh	light, dark gray lime-stone	boulder alluvium, gravel	45	59	52/55	40	13	8/14/68	100 yds. of Mtn. Lake House in Marshall Creek
Paradise Twp.									
Dcw	shale limestone	over-burden	35	400	70/300	12	50	7/15/68	Timber Hill Ski Area N. Henryville
Dcw	red rock	broken shale	20	147	65/80	3	65	9/18/68	same
Dcw	red rock	same	30	325	75/130	5	75	8/31/68	same
Dcw	limestone	over-burden	88	220	170/210	8	50	5/21/68	same
Dmh	shale	ground	5	80	35/45		30	8/23/67	Beacon Hill Rd. above Lee's gravel pit

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SURFICIAL GEOLOGY OF THE EAST STROUDSBURG 7½ QUADRANGLE, MONROE COUNTY, PENNSYLVANIA

By

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